

CHOICE OF ELECTROLYTE FOR ELECTROCHEMICAL MACHINING FROM THE POINT OF VIEW OF INTERGRANULAR CORROSION

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In a study of electrochemical drilling, the influence of the electrolyte composition on intergranular corrosion of various nickel alloys and of hardenable stainless steel was investigated. The nickel-base alloys did not undergo intergranular corrosion in a solution of 15% NaNO₃ + 20% NaClO₃ + 65% H₂O, but they did so in solutions of NaNO₃ alone and in solutions containing NaCl. Stainless steel did not corrode in any of the electrolyte solutions used.

Electrochemical machining (ECM), based on controlled anodic dissolution of metal workpieces^{1,2}, is one of modern methods of machining very hard metals. Its main advantage is that the rate of machining is independent of the hardness of the material. Moreover, the machined surface is free of microfissures and internal stress, whereby the service life of periodically stressed components³ is increased by 7–30 percent.

The quality of the machined surface, however, may be substantially impaired by intergranular corrosion during electrochemical machining if an unsuitable electrolyte is used. Intergranular corrosion impairs the physico-mechanical properties of the workpiece and must therefore be prevented by choosing suitable machining conditions. This is especially important in the case of components exposed to high temperatures. The aim of the present work is to find such conditions at which the intergranular corrosion during electrochemical machining of nickel-base alloys and hardenable corrosion-resistant steel is minimized.

EXPERIMENTAL

The intergranular corrosion was studied in the case of electrochemical drilling⁴. The tool (cathode) was a metal capillary with an electrically insulated outer surface. The capillary moved at a constant velocity, v , with respect to the workpiece (anode, Fig. 1), and an electrolyte flowed through it under pressure at a velocity v_E . The electrode distance⁵ was about 0.2 mm. The electrode system was dipped under the electrolyte level.

During the electrolysis, the anodic dissolution took place only in the proximity of the noninsulated orifice of the capillary. The electrolysis products (gases, metal hydroxides) were removed

by the streaming electrolyte. The process resulted in the formation of a hole whose diameter was controlled by the current intensity and the velocity of shifting the capillary against the anode.

TABLE I

Composition of anode materials (in mass percent)

	ZhS6K	EI617	LVN10	EI437	AK1 Poldi
Ni	67	74	74	74	1.65
Cr	10.75	14.5	12.5	20.5	11.25
Fe	2.0	5	0.5	1.0	82
Al	5.5	2.0	6.0	0.8	—
Mo	4.15	3.0	4.5	—	0.42
Nb + Ta	—	—	2.0	—	—
Co	4.5	—	—	—	—
Ti	2.85	1.05	0.7	2.7	—
W	5.0	—	—	—	1.8
Zr	—	—	0.10	—	—
V	—	1.3	—	—	0.24
C	0.17	0.06	0.03	—	0.13
B	0.02	0.2	0.010	0.01	—
Si	0.6	0.6	0.5	—	0.6
Cu	—	0.07	0.3	0.07	0.3
Mn	0.6	0.5	0.2	0.4	0.75
S	0.01	0.01	0.015	0.07	0.025
P	0.01	0.015	0.015	0.016	0.03
Ce	0.015	0.2	—	0.01	—
Pb	—	—	—	0.01	—
Sn + Sb + Bi + As	—	—	—	1.0	—

TABLE II

Solutions used for electrochemical machining

Symbol	Composition, mass %
<i>I</i>	15% NaNO ₃ , 20% NaClO ₃
<i>II</i>	15% NaNO ₃
<i>III</i>	25% NaCl
<i>IV</i>	8% NaNO ₃ , 6% NaCl
<i>V</i>	4% NaNO ₃ , 24% NaCl

The experimental setup is shown schematically in Fig. 2. The electrolyte from reservoir 1 is transferred by dosing pump 2 through a system of safety and control valves 3 and air chamber 4, serving to compensate pressure shocks in the system, into the drilling head, where it passes through a fine sieve 5 to remove eventual impurities, and flows into the capillary cathode 6. The drilling head with the cathode moves at a constant velocity v toward the workpiece 7. The elec-

TABLE III

Intergranular corrosion of machined surfaces in terms of the maximum depth of corrosion (μm). Numbers in parentheses indicate the number of experiments; 0 denotes no corrosion observed

Material	15% NaNO_3 20% NaClO_3	15% NaNO_3	25% NaCl	8% NaNO_3 6% NaCl	4% NaNO_3 24% NaCl
EI 437	0 (1)	—	0 (1)	—	0 (1)
EI 617	0 (8)	70 (3) 0 (1)	60 (2)	40 (2)	—
LVN10	0 (3)	0 (2)	0 (1)	—	—
AK1 Poldi	0 (6)	—	0 (2)	—	—
ZhS6K	0 (3)	—	—	—	—

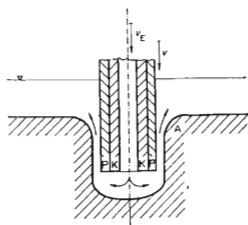


FIG. 1

Principle of electrochemical drilling. A anode (drilled material); K cathode (tool); P insulation; v velocity of motion of the cathode; v_E streaming velocity of electrolyte (indicated by arrows)

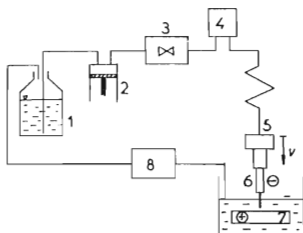


FIG. 2

Scheme of the apparatus for electrochemical drilling. 1 electrolyte reservoir; 2 dosing pump; 3 safety and control valves; 4 air chamber; 5 sieve; 6 capillary (cathode); 7 workpiece (anode); 8 sucking and periodic filtration of electrolyte; v velocity of motion of the cathode

trodes are immersed in the electrolyte, whose level is maintained constant by the suction device 8. Used electrolyte is periodically filtered and recirculated into the reservoir 1. The electrolysis current was maintained constant with an accuracy of $\pm 0.1\%$. Sparking at the electrodes⁶ was prevented by choosing a suitable current density at the cathode.

To evaluate the intergranular corrosion, about 10 mm thick metal samples were provided with electrochemically drilled holes of about 1 mm diameter. They were then cut in a plane passing through the hole axis, ground, and a metallographic analysis was carried out both in the etched and nonetched states⁷.

The cathode from a corrosion-resistant steel 17 241 was insulated by an electrophoretically deposited layer of a type S-2201/0625 enamel (Chemolak, Smolenice, ČSSR), which was 30 μm thick. The outer diameter of the noninsulated cathode was 0.6–1.0 mm and its inner diameter 0.4–0.5 mm. The workpieces were made of alloys of the type ZhS6K, EI617, LVN10, and EI437, and of the corrosion-resistant steel Poldi AK1 (Table I). The composition of the electrolytes is indicated in Table II. The rate of flow of the electrolyte was in the range (2.5–3.7) $\cdot 10^{-6} \text{ m}^3/\text{s}$. The electrolytic current was 0.55–1.00 A according to the cathode diameter.

RESULTS AND DISCUSSION

The results of the metallographic examination of 24 samples of holes in the materials EI 437, EI 617, LVN 10 and Poldi AK1 machined in the electrolytes given in Table II are summarized in Table III. It is apparent that only the alloy EI617, if machined in electrolytes containing NaCl or in pure NaNO_3 solution, shows intergranular corrosion. This is illustrated in Figs 3 and 4. The sensitivity of the alloy EI617 toward intergranular corrosion might be caused⁸ by its two-fold content of carbon as compared with the alloy LVN10, which has a similar composition but resists intergranular corrosion under the same conditions. Another explanation could be based on the difference in the content of admixtures (V, B, Ce). The elucidation of this question would require a further work. Nevertheless, none of the samples under study was subject to intergranular corrosion during machining in a solution of 15% NaNO_3 and 20% NaClO_3 in water (electrolyte I in Table II), which can be recommended as a universal electrolyte with a passivating action for electrochemical machining. This conclusion was substantiated by additional experiments with three samples of the alloy ZhS6K, three samples of the alloy EI617, two samples of LVN10, one of EI437, and three samples of Poldi AK1 steel. Again, no intergranular corrosion was observed. Hence, electrolyte I (Table II) seems to be universally applicable.

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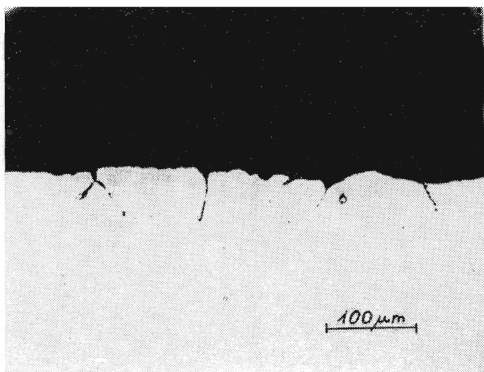


FIG. 3

Character of intergranular corrosion of EI617 alloy in 15% NaNO_3 . Magnification $200\times$, nonetched

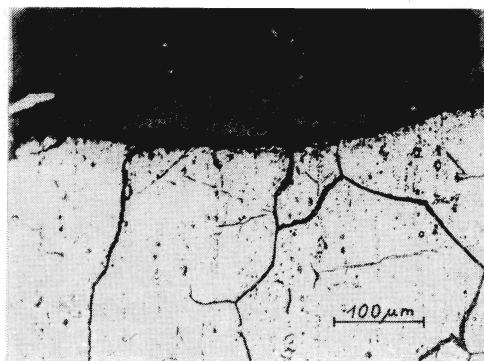


FIG. 4

Character of intergranular corrosion of EI617 alloy in 15% NaNO_3 . Magnification $200\times$, etched electrolytically in 10% oxalic acid